INFLUENCE OF CARTON STACKING PATTERNS ON PEAR COOLING RATES

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PREFACE

The authors appreciate the help of the members of the Oregon-Washington-California Pear Bureau who made facilities and fruit available for the experiment. Without the cooperation of these members, this work could not have been conducted. Acknowledgment is made of the assistance given by R. A. Patterson, secretary, Oregon-Washington-California Pear Bureau; Ray Baker, chairman, Research Committee of the Pear Bureau; and James Main, representative, Container Corporation of America, in arranging for various details and test locations.

This is an interim report on one phase of the long-range research projects of the Agricultural Marketing Service to improve the operation and design of cold storage houses for tree fruits and the postharvest handling of these fruits.

SUMMARY

A new type of fiberboard carton for storing and shipping Anjou pears was tested in pilot plant operations in the Pacific Northwest. Results of the tests revealed that stacking arrangements with this carton can affect the cooling of the pears and, consequently, their condition at the end of the storage period.

When containers were stacked to allow some air flow between the stacks, from 75 to 82 hours were required to remove from pears in these multiple-layer fiberboard cartons enough of the field heat to retard ripening, compared with 50 hours for those in wooden boxes. Pears in cartons stacked without side exposure and with only one end exposed required far more time for removal of field heat than those in wooden boxes similarly stacked--200 hours for the cartons compared with 68 for the wooden boxes.

Differences between stabilized storage temperatures of pears in the new cartons and those in wooden boxes were much greater when the containers were tightly stacked than when more of their surface was exposed to air flow. The wooden boxes had an advantage in tight stacking because the bulge in the packed boxes allowed some air flow between the stacks.

The increased cooling time and higher storage temperature of the fruit in tightly stacked cartons resulted in loss of quality in the pears.

In view of these results, tight stacking of fiberboard cartons should be avoided. If fruit is packed before cooling, more attention should be given to stacking patterns; past experience with wooden boxes is not a reliable criterion for evaluating stacking arrangements.

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BACKGROUND OF THE STUDY

The pear industry became interested sometime ago in using corrugated paper cartons for packing and storing pears. However, it was believed that the cartons and stacking patterns used in storage influenced the cooling rate of the packed product. To find out what this influence was, a study was undertaken.

Two types of cartons and several stacking patterns were studied under commercial and laboratory conditions. The cartons were selected by the Research Committee on the Oregon-Washington-California Pear Bureau in 1953 and 1954 as promising containers for use by the pear industry. In 1953 a pilot packing and storing operation was conducted in a plant in the upper Wenatchee Valley, and in 1954 pilot operations were conducted in the 4 principal winter pear growing districts in the Pacific Northwest; i. e., Medford and Hood River, Oreg., and Yakima and Wenatchee, Wash. The laboratory work was conducted at the Agricultural Marketing Service laboratory at Wenatchee.

Although the tests with these cartons covered labor requirements for various phases of the operations as well as shipping performance, this report deals only with the cooling and storage characteristics of the cartons compared with wooden boxes and the effect of these characteristics on the quality of the stored product.

CARTONS STUDIED

The carton selected for the 1953 tests was made of a single layer of double-faced corrugated fiberboard that was folded and stapled together upon assembly; the top consisted of overlapping flaps. These flaps were stapled together after the carton was packed. This same carton was also used at Hood River, Oreg., during the 1954 tests but was strengthened by the addition of a veneer liner for sides and bottom. The liner was placed inside the carton after assembly. Figure 1 shows a carton of this type with the veneer liner in place.

The carton selected for the 1954 tests was much stronger and of rather unusual construction. Essentially, it consisted of an inner and an outer shell, each cut from a single piece of fiberboard and assembled by folding, without stapling. The inner half of the assembled telescope-type carton had 3 layers of corrugated board on the ends and sides and 1 layer on the bottom, and the outer half had 2 layers on the ends and top and a single layer on the sides. After the inner container was packed with fruit, the outer shell was placed over it, and the entire assembly inverted for handling and stacking. The assembled carton then was 5 layers thick on each end, 4 layers on each side, 2 layers on the bottom, and 1 layer on the top. Figure 2 shows the 2 shells after assembly, and figure 3 shows the inner shell of an empty carton partly removed from an outer shell.

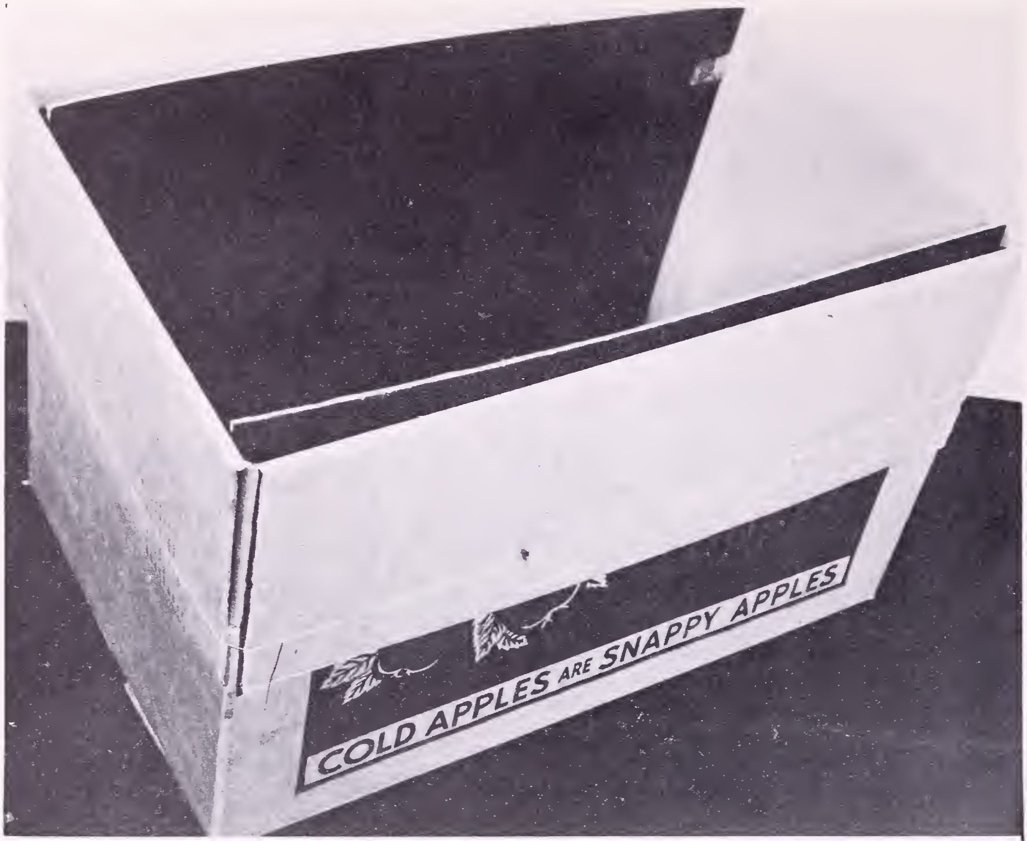

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Figure 1. --Single thickness fiberboard carton similar to one used in the 1953 tests, with the veneer liner used in 1954 at Hood River, Oreg., shown in place.

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Figure 2. --Telescoping type of carton used in the 1954 tests, showing the inner and outer shells after assembly from precut fiberboard sheets.

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Figure 3. --Telescoping type of carton used in 1954 tests, with inner shell partly removed from outer shell.

STACKING METHODS USED

Different methods of stacking were used at each of the plants. These stacking methods are described in table 1. The stacking methods were determined by the warehousing procedures and customs of the storage plants in which the tests were conducted. Also included in table 1 are details of the refrigeration equipment and air circulation systems used. Figures 4 through 7 illustrate the stacking arrangements used in the 1954 tests. Note that at Hood River both the 1954 carton and the 1953 carton with veneer liner inserted were tested.

METHOD OF CONDUCTING THE TESTS

At the time of packing the fruit was examined for finish and appearance, its firmness determined with a Magness-Taylor pressure tester, and soluble solids checked with a refractometer. One test carton and one standard wooden box from each pilot plant were observed in the Wenatchee laboratory during the storage season. Weight loss, shriveling, bruising, firmness, total solids, and degree of ripeness were recorded after a season's storage at 31° F. and 84 percent relative humidity.

Also, on February 8, 1955, a fiberboard carton was taken from the storage with the most unfavorable cooling record and held in the laboratory storage until examined at the end of the storage season. In this particular plant, the difference between the cooling in the wooden boxes and in the cartons was far more marked than in any of the other storages. A duplicate of the sample being held in the laboratory was stored in the plant so that the effect of the slower cooling on the quality of the fruit could be observed.

Fruit temperatures in paired test cartons and standard wooden boxes, and air temperatures adjacent to the test containers, were recorded continuously at a number of representative locations in each plant during the initial cooling. The paired containers were located next to the top and next to the bottom of the stacks. In the Wenatchee storage, additional readings were taken intermittently in the stacks with the greatest temperature differences for a period of 47 days after the continuous recorder was removed. The continuous records were obtained by using a multipoint recording potentiometer connected to copper-constantan thermocouples placed at the test locations. The recorder and some wiring are visible in figure 7.

Cooling coefficients for each test location were calculated by previously published methods.[1] These coefficients were averaged for each of the various types of containers under test at a given storage. The average cooling coefficients were converted to characteristic cooling time values, Z, the time required to reduce the fruit temperature one-half of the range between initial temperature and room temperature. Twice this time, 2Z, reduces the fruit temperature three-quarters of this range and, for all practical purposes, represents the time required to remove three-quarters of the field heat from the fruit. With the initial fruit temperatures and room temperatures that prevailed in these tests, removal of three-quarters of the field heat reduced the temperature of the pears to the point at which ripening was substantially retarded.

The difference between the temperature of the fruit in the wooden box and the test carton in each paired location was analyzed at the end of the test run. An approximation was made of the number of days required for the difference in temperature in each storage to stabilize. Stabilized differences in temperatures of containers at a given location indicate the cooling characteristics of the different containers, because fruit produces heat while in storage and the fruit and air temperatures must differ to make this heat flow to the air. If it is assumed that the air temperature is the same for two containers at a given location, it follows that if pears in one container are consistently warmer than in the other, the warmer container must be more resistant to heat flow.

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[1] Sainsbury, G. F. Improved Fruit Cooling Methods. Refrig. Eng. 59(5): 464. May 1951.

Table 1.--Stacking arrangement and refrigeration system used in pilot plant storage tests in 1953 and 1954

Location of plant and date of test	Height of stacks and stacking arrangement of containers	Description of refrigeration system and air circulation plan
1954 TESTS		
Medford, Oreg. Sept. 7 through 15	7 containers in stack; stacks arranged with side space; end space irregular; wooden boxes placed in carton stacks	Air is cooled in central station brine spray air washers, circulated to room and down through stacks, and leaves through floor slots to duct spaces beneath the floor
Hood River, Oreg. Sept. 17 through Oct. 2	9 containers in stack; stacks arranged with ends butted but with side space; wooden boxes placed in carton stacks	Pipe coil room with auxiliary fans for air circulation
Yakima, Wash. Sept. 14 through 24	13 containers in stack; chimney stacks; wooden boxes placed in carton stacks	Pipe coil room with auxiliary fans for air circulation
Wenatchee, Wash. Sept. 28 through Oct. 13	11 containers in stack; two rows stacked tight with ends butted--no side space--only one end of each box exposed. Wooden boxes in similar pair of rows between double carton rows	Room cooled by brine spray air unit, air distributed through supply ducts of walls and down center of room, and air returns through room to centrally located unit
1953 TESTS		
Wenatchee, Wash.[1] Sept. 22 through Oct. 8	18 containers in stack; pallet stacks--cartons placed in pallet load of wooden boxes	Room cooled by dry finned coil air unit. Air circulated from overhead duct to side-walls of room and down walls.

[1] Different storages were used for the 1953 and 1954 tests in the Wenatchee area.

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Figure 4. --Stacking arrangement used at the Medford, Oreg., plant, showing spaces between stacks that allow side exposure. Cold air flows down through stacks to exhaust through floor slots beneath the stacks.

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Figure 5. --Stacking arrangement used at the Hood River, Oreg., plant showing wide spaces between sides of cartons. Test wooden boxes and the 1954 experimental cartons are shown in stacks of 1953 cartons with veneer liners. These rows of stacks were later finished out to the aisle to cover test locations.

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Figure 6.--Stacking arrangement used at the Yakima, Wash., plant. Boxes are stacked 13 high in chimney stacks. Chimney is formed as in insert.

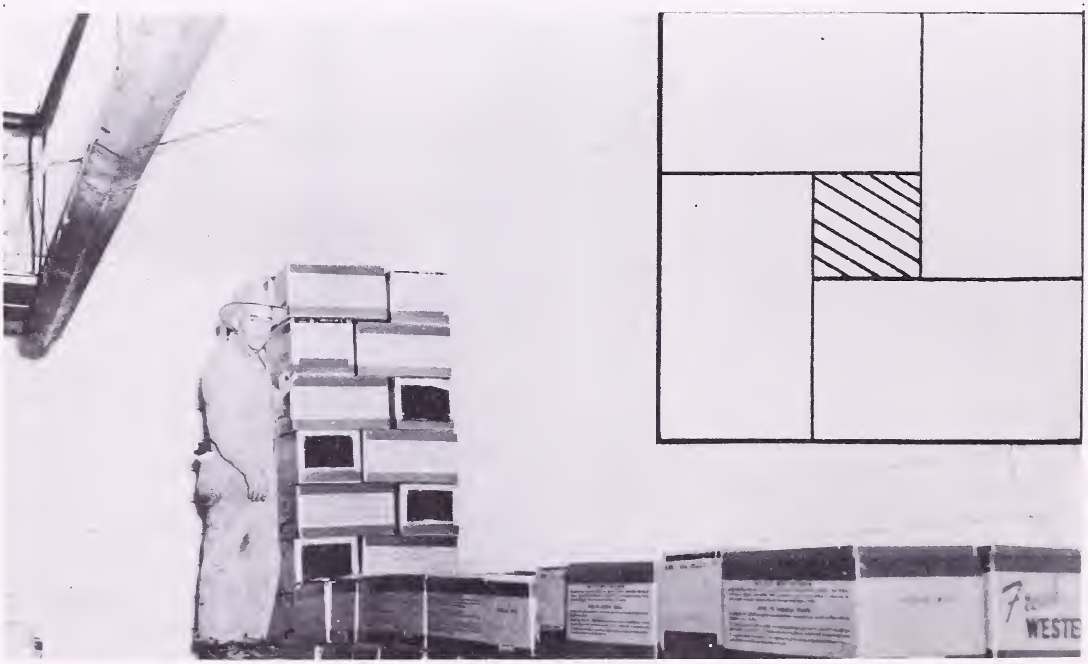

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Figure 7.--Stacking arrangement used at the Wenatchee, Wash., plant, showing tight stacking of double rows, with double row of wooden boxes in center of block for comparison. Temperature recorder is shown in place in front of post.

RESULTS

The data on cooling performance in the various storages are summarized in table 2. The average temperature differences between the fruit in wooden boxes and in cartons at paired locations and the time required to reach a stabilized difference are given in table 3. In all locations, the pears in the wooden boxes were cooler than those in the cartons at the end of the test period.

In the Yakima plant, the record obtained was not suitable for determining cooling performance; however, temperature differences at paired locations were about the same as those observed at the Medford and Hood River plants. Therefore, it is concluded that the cooling performance was similar.

Where the stacking arrangement allowed some side exposure of the cartons for air flow, 75 to 82 hours were required to remove three-quarters of the field heat from the cartons, compared with 50 hours for the wooden boxes (figs. 4 and 5). In tests with apples packed in wooden boxes, the time required to remove three-quarters of the field heat was approximately 55 hours in individual stacks and from 65 to 75 hours in palletized stacks. From this it appears that the increased cooling time required for cartons favorably stacked, compared with wooden boxes, is about the same as the increased time required when wooden boxes are palletized.

In the Wenatchee plant, where the cartons were stacked without side exposure and with only 1 end exposed, 200 hours were required for removal of three-quarters of the field heat, compared with 68 hours for similarly stacked wooden boxes (fig. 7). The temperature differences at paired locations in this storage were also much greater than those in the other pilot plants. The location near the top of the stack stabilized with the carton almost 3 degrees warmer than the wooden box and required 5 weeks to reach a stabilized difference. With the exception of the Medford plant, the temperature differences in the other storages stabilized at less than 1 degree after a period of 1 to 2 weeks. Since the Medford record was taken for only 1 week, there is some question whether the 1.7° average for the upper locations is actually a stabilized difference; in all probability the temperature stabilized with about a 1-degree difference.

Table 2.--Cooling performance whereby various types of cartons and wooden boxes packed with Anjou pears were compared, 1953 and 1954 seasons

Type of container and location of plant	Initial fruit temperature	Average room temperature	Time required to remove 3/4 of field heat (2Z)[1]	
			Wooden boxes	Cartons
	Degrees F.	*Degrees F.*	*Hours*	*Hours*
Wooden boxes and 1954 cartons:				
Medford, Oreg..............	58 to 70	29.3	51	82
Hood River, Oreg...........	56 to 62	30.0	50	75
Wenatchee, Wash............	52 to 56	29.8	68	200
Wooden boxes and 1953 cartons with veneer liners:				
Hood River, Oreg...........	56 to 62	30.0	50	70
Wooden boxes and 1953 cartons without liners:				
Wenatchee, Wash............	58 to 61	31.2	74	79

[1] The symbol 2Z was used to represent the time required to remove three-quarters of the field heat from the fruit.

Table 3.--Differences in temperature of Anjou pears in wooden boxes and in various types of cartons at paired locations, 1953 and 1954 seasons

Type of container and location of plant	Duration of test	Number of degrees by which pears in wooden boxes were cooler than pears in cartons at end of test period		Time to reach stabilized temperature difference	
		Upper position	Lower position	Upper position	Lower position
	Days	*Degrees F.*	*Degrees F.*	*Days*	*Days*
Wooden boxes and 1954 cartons:					
Medford, Oreg.........	7	1.7	0.7	7	6
Hood River, Oreg......	15	.5	.3	11	9
Yakima, Wash..........	10	.8	.1	5	6
Wenatchee, Wash.[1].....	15	5.2	1.7	35	20
Wooden boxes and 1953 cartons with veneer liners:					
Hood River, Oreg......	15	.5	.3	10	9
Wooden boxes and 1953 cartons without liners:					
Wenatchee, Wash.......	16	.1	.1	14	14

[1] An intermittent record was made for 47 days after this 15-day continuous test. After the temperature difference between the wooden box and the carton stabilized, the difference at the upper location was 2.9° F. and at the lower location, 1.4° F.

The comparisons made at Hood River included the 1953 carton with a veneer liner insert. Although these cartons cooled slightly faster than the 1954 carton, the difference was not great, and they did not cool as rapidly as the wooden box. The 1953 test did not show much difference between the cooling performance of the single thickness fiberboard carton and that of wooden boxes. Furthermore, final temperature differences between carton and wooden box at paired locations were negligible.

Data regarding the initial condition of the pears are given in table 4. The fruit from all four areas varied only slightly in firmness; this quality is generally considered to be the most reliable index of maturity. The Medford and Wenatchee pears were not quite as firm as those from the other districts and were more advanced in color. Soluble solids did not appear to be closely correlated with firmness or color.

The experimental fruit stored in the laboratory at Wenatchee was removed April 13 after approximately 7 months of storage at 31° F. The fruit condition data taken at that time are summarized in table 5. Differences in weight losses between the fruit in the fiberboard carton and that in the wooden boxes were not noticeable, although there was a slight difference in favor of the fiberboard container.

Fruits showing any visible shriveling were tabulated as shriveled. Consequently, many pears with only very slight shriveling near the stem contributed to the high percentage figures. This type of shriveling does not detract materially from the appearance of the fruit.

Except for the fruit from the Medford area, the pears in the fiberboard carton were generally slightly riper after storage than those in wooden boxes as judged by firmness and color. In the carton taken from the Wenatchee pilot plant on February 8, where stacking had been least favorable for cooling, the fruit was considerably riper than the test fruit held in the laboratory storage, where the sides and ends of the test containers were

exposed to the cold air and conditions were favorable for cooling. The differences in ripeness are indicated by the color and firmness figures in table 5.

Table 4.--Condition of Anjou pears of four districts at time of packing, 1954

Pear district	Firmness	Soluble solids	Observations on fruit
	Pounds	*Percent*	
Medford, Oreg................	14.7	14.2	Smooth, well finished, light green in color (color breaking)
Hood River, Oreg............	15.1	12.0	Fruits mostly green, some light green
Yakima, Wash................	15.0	13.8	Fruits mostly light green, some green
Wenatchee, Wash.............	14.6	12.6	Fruits mostly light green, good finish

Table 5.--Condition of Anjou pears in 1954 style experimental fiberboard cartons and in standard wooden boxes after storage at 31° F. and 84 percent relative humidity for 7 months, April 13, 1955

Pear district and type of container	Weight loss	Fruits visibly shriveled	Firmness	Soluble solids	Color[1]
	Percent	*Percent*	*Pounds*	*Percent*	
Medford Oreg.:					
Experimental carton......	2.9	35.2	9.2	13.6	3.00
Standard box.............	3.6	40.0	8.7	15.0	3.30
Hood River Oreg.:					
Experimental carton......	4.2	35.0	11.1	12.2	2.45
Standard box.............	4.5	50.0	12.2	12.8	2.20
Yakima, Wash.:					
Experimental carton......	2.8	63.0	8.8	14.0	3.10
Standard box.............	3.4	61.0	10.5	13.0	2.50
Wenatchee, Wash.:					
Experimental carton......	2.9	54.2	9.3	12.6	2.50
Standard box.............	3.0	62.7	10.2	12.5	2.30
Experimental carton from commercial storage, 2/8.....................	---	62.0	8.0	13.0	3.00

[1] Determined by use of Standard Ground Color Chart for Apples and Pears in Western States, U. S. Department of Agriculture: No. 1, green; No. 2, light green; No. 3, turning; No. 4, yellow.

CONCLUSIONS

These tests illustrate a very important point: Stacking arrangement may have a more adverse effect on the cooling of fruit in cartons than on the cooling in similarly stacked wooden boxes. Why? Container shape characteristics provide an answer.

The straight surfaces of the carton allow absolutely tight stacking, whereas the packed standard wooden box stacked on its side presents the bulged top and bottom to the adjoining stack. The contact between stacks, at the crown of the bulge, is only a small percentage of the surface. Consequently, most of the bulged surfaces are available to transfer heat to the air spaces. When the two types of containers are stacked in the manner used at the Wenatchee pilot plant (fig. 7), the box has about 4 times as much exposed surface as the carton. The fruit in the wooden box cooled 3 times as fast as that in the carton. This difference in cooling time indicates that, although the surfaces exposed to the small, irregular chimneys caused by the bulge in the boxes were not as effective for cooling as the well-exposed end surface, they were effective enough to produce a great overall difference in favor of the wooden box.

In the other test locations, where side exposure was provided, the wooden box had approximately the same exposed area as the carton, and the difference observed in cooling performance is probably attributable to the insulating effect of the several layers of corrugated fiberboard.

When the cartons were well exposed to air for heat removal, as in the test containers stored at the laboratory, the difference in fruit condition in the wooden boxes an in the carton after a season of storage was just perceptible. However, a comparison of two cartons of fruit packed in the same plant but stored under different conditions showe that the fruit in the carton that had been subjected to tight stacking and very slow coolin was more advanced in color and ripeness than the test fruit cooled in the laboratory storage. The poorer quality of the sample subjected to tight stacking illustrates the detrimental effects of the resultant slow cooling.

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